The new version of the REgional MOdel REMO

REMO2020: On the way to a regional earth system model

Joni-Pekka Pietikäinen, Kevin Sieck, Lars Buntemeyer and Thomas Frisius

Climate Service Center Germany (GERICS)

REgional MOdel REMO:

- Regional climate model developed at Max-Planck Institute for Meteorology and currently maintained at the Climate Service Center Germany
- Successful history of being one of the best dynamical downscaling models
- Previous versions REMO2009/2015 used in CORDEX and CORDEX-CORE simulations
- The model had different versions under different names and not all development efforts were merged to the main model (branch)

REMO2020 version:

- The main tool for CMIP6 downscaling (CORDEX)
- The model core (Fortran) has been refactored into separate modules to follow the "open closed principle" (*open to extension, closed to modification*) as closely as possible → we can include external contributions more easily, such as a lake-model and dynamical vegetation, and activate these during a Python controlled configuration phase
- The I/O module has been restructured on code level and has now a stream-based flexible NetCDF4 I/O (supporting CF-conventions)
- Dynamical core: rewritten, includes the non-hydrostatic extension (for kilometer scale simulation) and a new mass conserving wet-core approach for water species
- Physics module: rewritten and restructured to optimize performance and includes almost all previous development branches. Also new development steps, for example a new aerosol climatology approach (MACv2-SP by default), a 3-layer snow module and a prognostic precipitation approach
- The model has been re-tuned for different resolutions separately (horizontal and vertical)

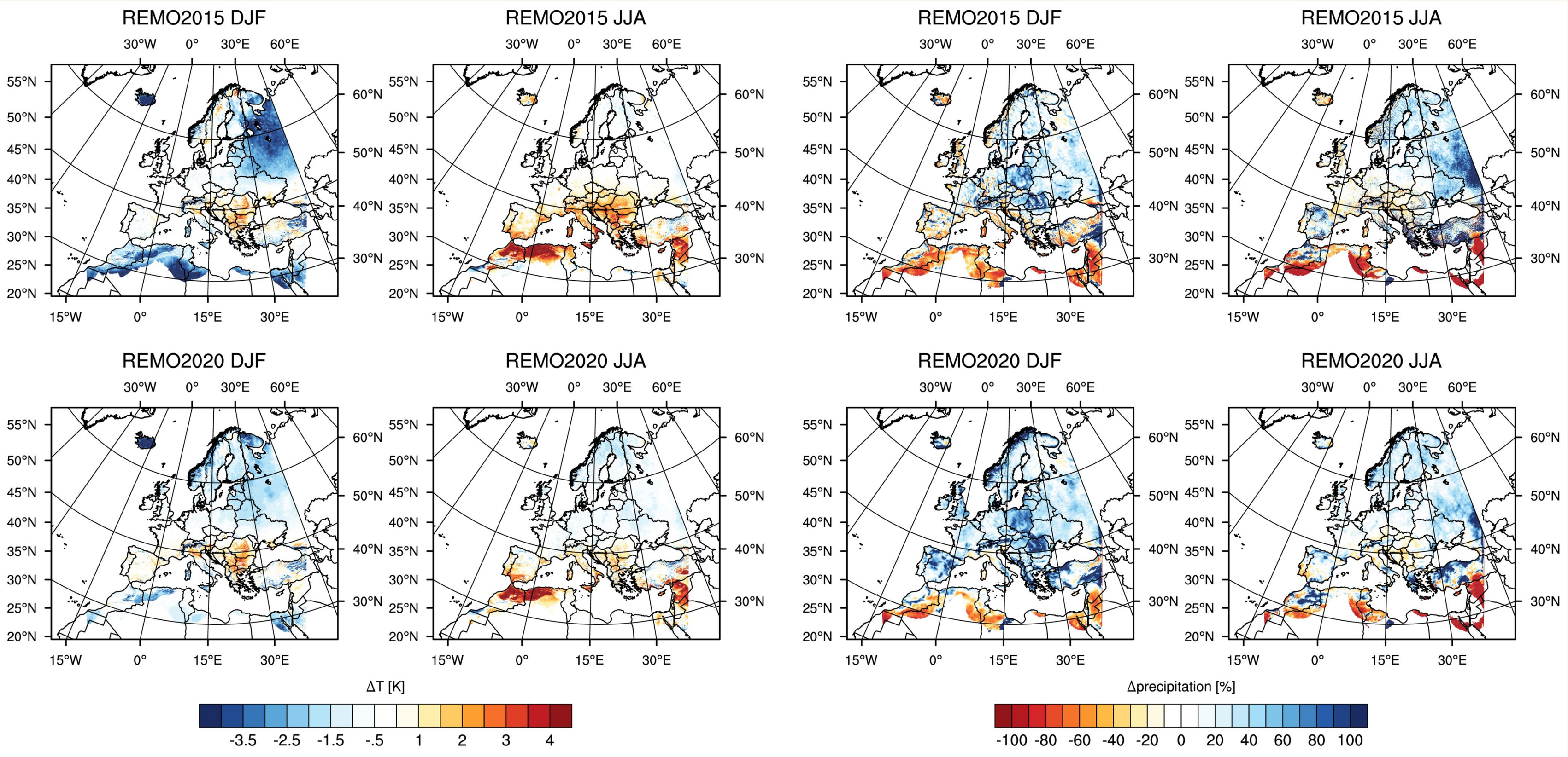

Figure 1: Temperature and precipitation biases from REMO2015 and REMO2020 against E-OBS data for the time period of 2001-2010

- **Figure 1 shows the 2-m temperature and precipitation biases against E-OBS data. REMO2020 shows overall much better agreement than REMO2015**
  - **The horizontal resolution was 0.11° and vertically we used 27-levels**
- **The biggest differences in physics between the two model versions in Figure 1 were the new modules used with REMO2020: the FLake lake model, the MACv2-SP aerosol climatology and a 3 layer snow module**
- **The configuration of the convective parameterization (Tiedke) has been changed. Our tests show that on EUR-11 domain, the deep and mid-level convection cause patchy precipitation fields and they have been switched off (Eu-CORDEX initiative)**
  - **Tests also show that this is not the case for all domains. For example, simulations for Africa domain using the same 0.11° resolution have shown that all components of the convective parameterization have to be used**

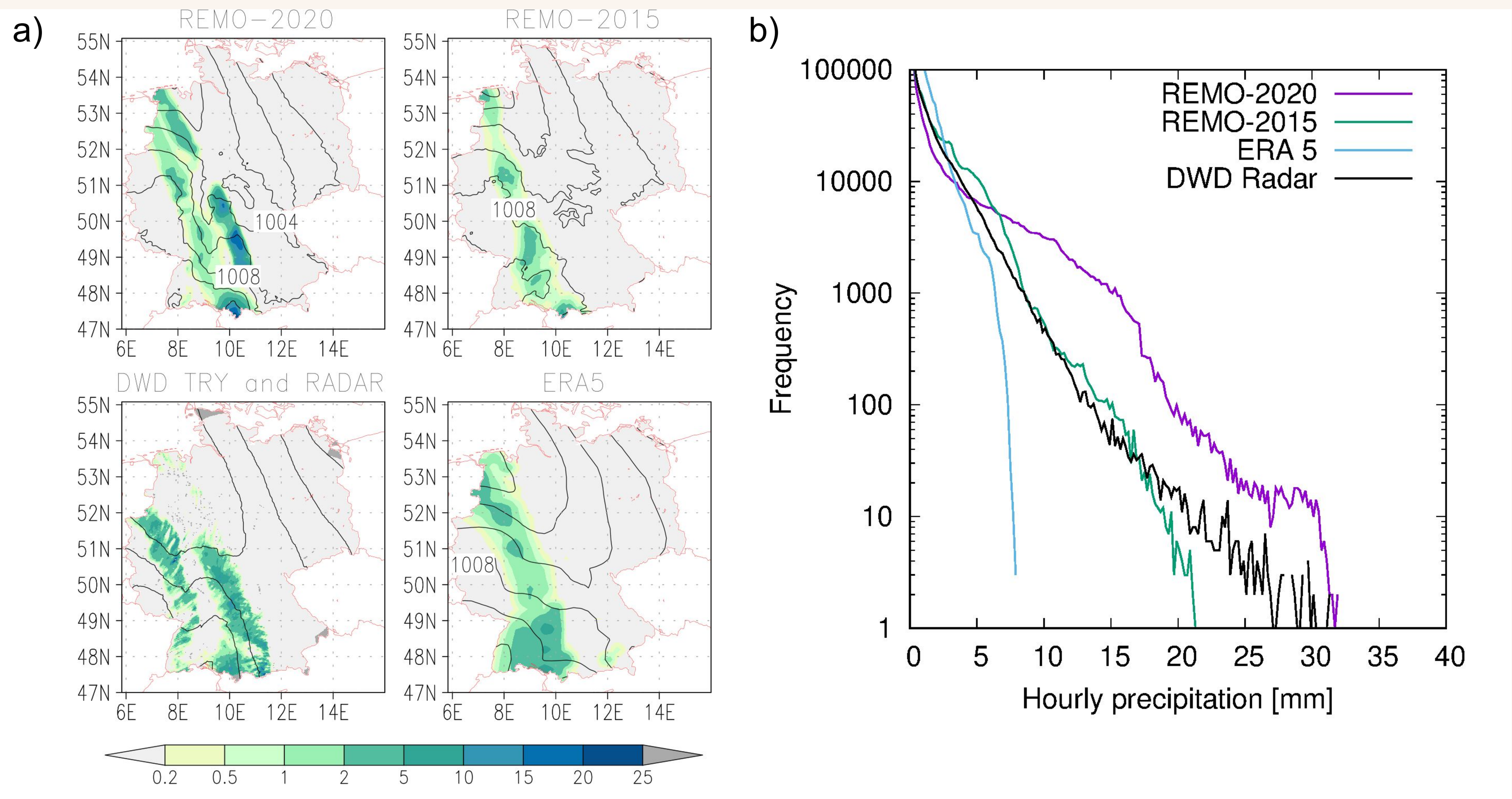

Figure 2: a) hourly precipitation (shadings, mm) and sea level pressure (contours, hPa) on 4th July 2005 at 16UTC deduced from the REMO simulations, DWD TRY data, DWD Radar data and ERA5. b) frequency distribution for the 4th of July 2005

- **Figure 2 shows results of convective cold front simulations by REMO using the nonhydrostatic high resolution (0.0275°) setup. The convective parameterization is switched off. The comparison of precipitation with DWD radar data and ERA-5 reveals the added value by downscaling. Extreme precipitation is reproduced quite well by REMO while in ERA-5 the precipitation pattern is smoother and the maxima are always below 10mm/h. REMO2020 shows a better reproduction of the DWD radar field than REMO-2015 and it captures extremes up to 30mm/h**

Towards a regional earth system model RESM

- The new modular structure of REMO2020 makes coupling of other model components, such as regional ocean model, easier than in the earlier REMO versions
- Passive module approach supports the concept of including the necessary components of a RESM and makes their implementation more efficient
- REMO2020 has a semi-automatic surface tile/fraction system that utilizes Fortran procedure pointers and surface components are mainly calculated only to those grid boxes that have a fraction of the component (automated and fast)
- We are working on a combined configuration towards the RESM

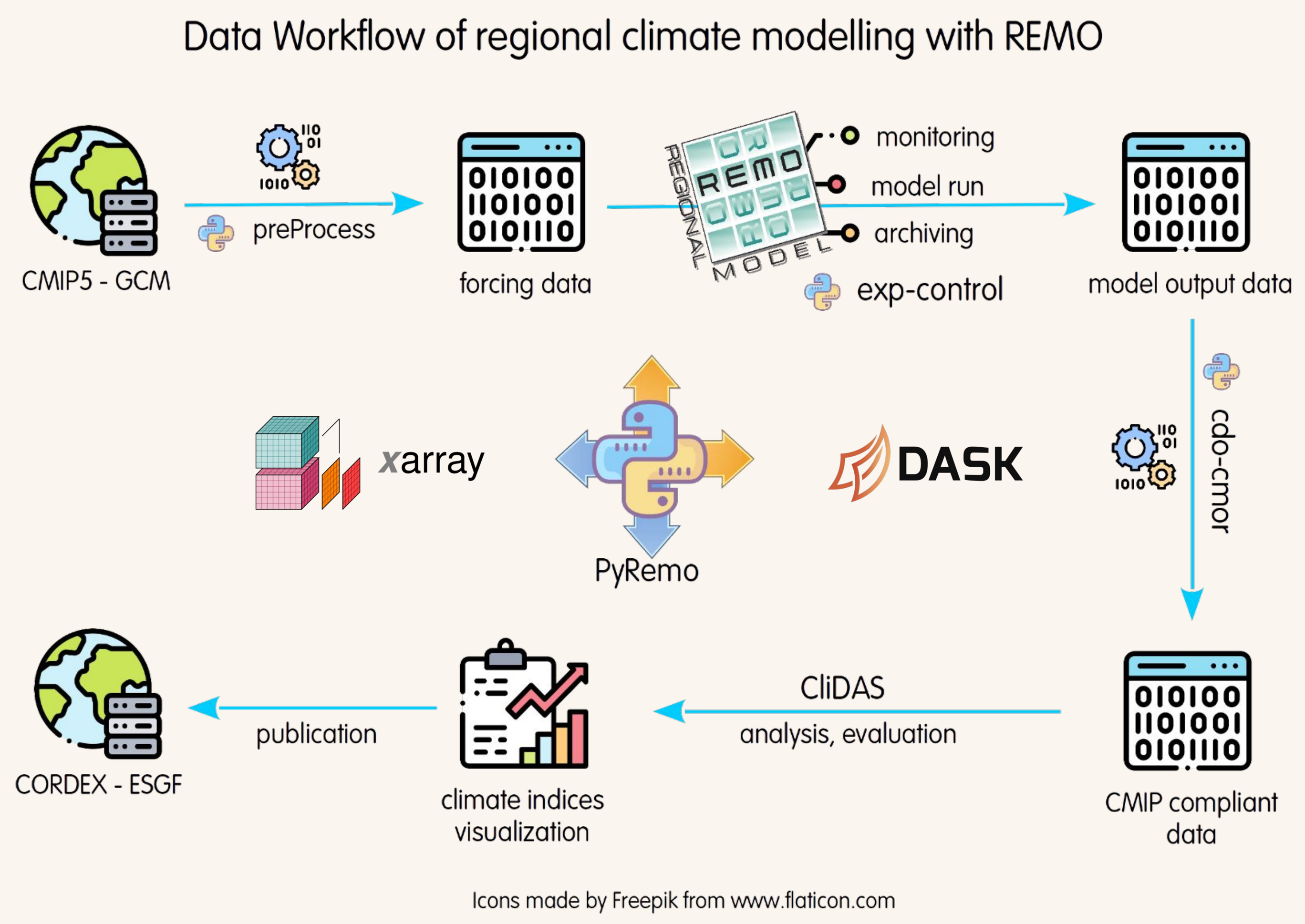

Figure 3: Schematic representation of the data workflow used with REMO

- **The data workflow shown in Figure 3. is currently the default GERICS approach and will be used for CMIP6 downscaling**
- **All steps from the forcing data to the processed, evaluated and released output data are done within Python based PyRemo library**
- **All steps shown in Figure 3 are done at DKRZ (currently on Levante) utilizing wide range of services ranging from HPC, GitLab and Jupyter Notebooks to data sharing**

Climate Service Center Germany (GERICS) • Helmholtz-Zentrum Hereon • Fischertwiete 1 • 20095 Hamburg • Germany

Joni-Pekka Pietikäinen • Email: Joni-Pekka.Pietikaeinen@hereon.de • www.climate-service-center.de